Bell Laboratories Record

Volume Seven FEBRUARY, 1929 *Number Six*

An Introduction to "Speech and Hearing"

By H. D. ARNOLD
Director of Research

With the publication of "Speech and Hearing" by Harvey Fletcher, Acoustical Research Director, the fifth book of the Bell Telephone Laboratories series comes into being. An introduction to this volume, contributed by Dr. Arnold, is here reprinted.

THE atmosphere of sounds in which we live ministers so constantly to our knowledge and enjoyment of our surroundings that through long familiarity we have come to feel, if not contempt, at least indifference toward the marvelous mechanism through which it works. Hearing, we are inclined to consider as little a matter for concern as breathing; and so long as our own faculty remains unimpaired we feel little curiosity concerning the provisions of nature either for ourselves or for others. When we hear too faintly or indistinctly we know we need only trace the sound to its source to hear its perfect form, for that is the method we have used from childhood in investigating the sounds of our immediate neighborhood.

Now with one broad sweep the barriers of time and space are gone and all the world becomes our vocal neighborhood. No longer can we transport ourselves to the origin of a sound and thus become convinced that we are hearing it aright, for that origin may be thousands of miles away or may have vanished years before; and so we must establish a new method to measure the accuracy of the copy which reaches our ears. We must also find a clearer index to our satisfaction in it, for we are no longer concerned with the immutable provisions of nature but may approach at corresponding expense whatever perfection we may demand in our instruments of translation and reproduction. Thus the telephone and the phonograph should excite a keener interest in how we hear and in what measures our satisfaction in the speech and music they provide.

Our ears are only machines to translate air waves into a form suited to stimulate the auditory nerve;

and as machines we may measure and describe them in the same terms that apply to devices we ourselves construct. We may compare them as to performance, and may accommodate our devices to their requirements. But, to understand the mechanism of the ear is by no means to understand the act of hearing, for we have not heard until the brain has perceived the message sent by the auditory nerve. We cannot explain in precise mechanical terms how this is done, nor indeed have we any very clear comprehension of the process at present. Some important factors relating to the process of hearing we can, however, determine by measuring the least changes in sound which can be detected under a variety of conditions of pitch, loudness, and accompanying noise. Thus we may obtain a quantitative means of comparing individuals in this respect, and establish a standard of average hearing.

There is a most important factor in hearing, however, which is much more difficult of analysis and measurement. This is the individual's ability to recognize small defects in those sounds with which he has become especially familiar. We all know how quickly we note a slight change in a friend's voice, and with what uncanny skill a trained musician will detect minute imperfections in very complex sounds. Our approach to a quantitative understanding of the importance of this must be by an indirect method. First we must construct devices so perfect that even the keenest ear cannot find a flaw in their rendition, and then step by step we may introduce measured imperfections until an observer can detect a fault. In the response of individuals to this test there will, of course, be great differences; but when we have collated opinions from a wide variety of observers we may forecast in a reasonable way the degree of mechanical perfection that may be demanded of our instruments.

This, then, has been the philosophy of the investigation of hearing which has been carried on in Bell Telephone Laboratories during the past fifteen years: to get an accurate physical description and a measure of the mechanical operation of human ears in such terms that we may relate them directly to our electrical and acoustical instruments; to test the keenness of the sound-discriminating sense and find what is the smallest distortion which the mind can perceive and how it reacts to somewhat larger distortions; and thus to reach a reasonable basis of design both for separate instruments and for systems, as a whole, to give a proper balance between cost and performance.

With hearing, speech and music are linked inseparably for they only bring a meaning through our aural sense. It is an instinctive first thought that they must be heard to be criticized. They can, nevertheless, be investigated by mechanical means and be described in the same physical terms that we use in describing hearing; and thus to an extent we may consider them both objectively. But if we attempt to divide the study between speech and music we come at once upon the difficulty that speech conveys information by intonation as well as by articulate syllables; and this makes it infeasible to set a definite boundary between them. A division, however, between vocal sounds and instrumental sounds proves more useful, for in the one case we are limited by our vocal organs which we must take as they are, while in the other

we have a definite control and can adapt the nature and complexity of the sounds produced to conform to our sense of hearing and our musical appreciation. The investigation of speech and music has been governed by these general considerations. An attempt has been made to establish in definite terms the performance and limitation of the voice and, although so far in considerably less detail, to find the corresponding factors in instrumental music.

With a clear knowledge of the nature of the sounds that we must produce and the accuracy with which we must maintain their form, there remains the problem of securing instruments which are sufficiently refined for the purpose. Instruments of remarkable precision are required in the conduct of the investigation, since if we are to measure the smallest detectable variations in sounds we must obviously use equipment which is capable of a degree of exactness beyond these small quantities. Such instruments would appear at first sight not to have much utility outside the laboratory, since they are costly and often complicated and difficult to adjust.

It is interesting to note, however, that some of the instruments, in essentially their original laboratory form, have found other important uses. Indeed, a surprising number of modern acoustical accomplishments have come about through the use of slightly modified forms of the apparatus which was originally developed for these investigations. Modern phonographic records are produced with an electrical transmitter which was developed in the very early stages of these studies; and radio broadcasting has grown up around this same "microphone." The reproducing equipment of the modern phonograph and of the radio were predicated directly upon these investigations; and talking motion-pictures owe their success and much of their apparatus to this same source.

Although the results which relate to normal speech and hearing are naturally the most familiar and widely known, there have also been important outgrowths in the way of aids to those handicapped in one or the other of these faculties. In establishing the functioning of the average ear it was obviously necessary to investigate a large number of cases and among them some which departed rather widely from the average. For this study an instrument was devised, now known as the audiometer, which has put within the reach of all who need it the possibility of an accurate measure of their hearing. In quite analogous fashion there grew out of the investigation of the limits of hearing a better knowledge of ways to provide aids for those partially deaf; and it has even become possible to provide means of speech for some persons whose vocal cords are gone.

Valuable as these results are, economically the most important outcome of the work has been the increase of exact knowledge as to the requirements and limitations to be placed upon the transmission of speech in the telephone system. As time goes on there must be an evolution toward even greater perfection in those particular elements which are most important to intelligibility. The system is so large that the cost of such an evolution is immense and changes undertaken without an accurate knowledge of their value might lead to burdensome expenditures for disproportionate results; but, with the

facts established by this investigation in hand, we can weigh any contemplated change and judge whether it is the one that offers most improvement at the moment and what its ultimate effect will be in its operation with other elements of the system.

The work that Doctor Fletcher discusses drew at the start on all the acoustic knowledge available in the literature and during its progress every effort has been made to use to the best advantage the information found by other experimenters. For the most part, however, he describes experiments performed and conclusions reached in Bell Telephone Laboratories during investigations, captained in their early stage by Doctor Crandall and himself, for which since Doctor Crandall's death he has had the full responsibility. No one can speak with better knowledge of the facts or with more complete authority for the opinions he expresses.

The work is not complete—indeed some parts of it are hardly more than started; yet its results have been so great, both for the original purpose which was planned and for the many issues which have since arisen, that it presents a unique exemplification of the worth of systematic and sustained research; and Doctor Fletcher is to be congratulated that he has seen it through with such clear vision as permits its presentation in its present form.

BELL TELEPHONE LABORATORIES SERIES
of books published by
D. Van Nostrand and Company

TRANSMISSION CIRCUITS FOR TELEPHONIC COMMUNICATION
by K. S. Johnson

THEORY OF VIBRATING SYSTEMS AND SOUND
by I. B. Crandall

INTRODUCTION TO CONTEMPORARY PHYSICS
by K. K. Darrow

PROBABILITY AND ITS ENGINEERING USES
by T. C. Fry

SPEECH AND HEARING
by H. Fletcher

Development of the 1800-Pair Cable

By W. C. REDDING
Apparatus Development Department

OF the developments that during the past half century have brought the telephone system to its present state of usefulness and efficiency, none, perhaps, is more typical of steady improvement than is lead-covered cable. The growth from the fifty-pair of 1888 to the 1200-pair cable of 1912 has already been described in the RECORD.* As is commonly the case, however, difficulties become greater the further a development is carried. The step from 1200 to 1800 pairs, taken by the new development, although it represents no greater percentage increase in size than many of the preceding steps, and is even smaller than some, is a noteworthy achievement because with each increase in the number of pairs, and each decrease in size of wire, the difficulties of manufacture become greater.

With the increasing congestion in metropolitan areas, available space beneath the streets—where cables must be placed—is rapidly being used up. Added demands for power, light, water, transportation, and other utilities all require their share of this space. Obtaining a fifty per cent increase in the number of telephone wires that may be run through a duct is thus a real contribution to the growth and development of densely populated districts, and promises further economies in this and also other situations.

The largest cable existing previously used twenty-four gauge conductors wrapped with paper one-quarter inch wide and two and one-half mils thick, and its 1212 pairs, so insulated, were contained within a lead sheath of about two and five-eighths inches outside diameter. Cables of this diameter are the largest that can be pulled into many existing ducts, and so this outside diameter is one of the limiting factors of exchange-cable design. The problem, therefore, is not merely to make a cable with a greater number of conductors but to change the design and methods of manufacture so that the larger number of wires can be contained within the same size of sheath.

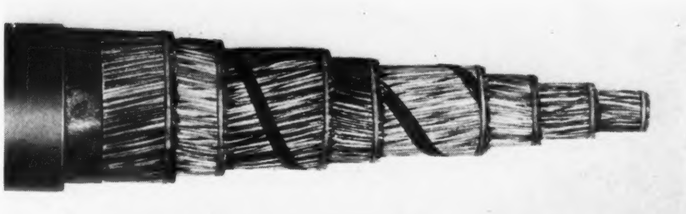


Fig. 1—A short length of 1200-pair cable showing layered construction

Obviously there are two possibilities; either the size of the conductors

* BELL LABORATORIES RECORD, *Vol. III, No. 5, pp. 146-152, January, 1927.*

or the thickness of the paper insulation may be reduced. There are difficulties involved in such reductions, however, both in the manufacture of the cable and in handling it after its completion. A cable must be pulled

Fig. 2—In this cross-section of the 1200-*pair cable also the layered construction is clearly evident*

into a duct from one manhole to the next, and possibly in the course of its life may be pulled out of one duct and into another. This pulling subjects the cable to strains and there is a possibility of breaks resulting in the conductors if they are too weak. Besides this the lengths of cable must be spliced in each manhole and because of the difficulty of handling smaller wires they cannot be reduced too far in size. In addition the factor of resistance can never be overlooked. The smaller the conductor the higher is the resistance and the greater, therefore, are the transmission losses.

In the course of development, projected to overcome these difficulties, many experiments were tried. Wires of different materials were experimented with to find out whether tougher substances, such as hard copper or bronze, would not add enough strength to offset a decrease in size. Results were not very satisfactory. The harder wire was springy and difficult to handle at the splices. Cables of soft copper but of smaller sizes were also experimented with and it was found that wire as small as twenty-seven gauge could be used.

Then, attention had to be given to the matter of paper. The thickness used with the 1200-pair cable was chosen principally for reasons of strength. In building up the cable the wires must be crowded together with considerable pressure and in handling the cable after completion, particularly in bending it, similar pressures are developed. If the paper is too thin there is danger that the conductor may cut through it at such times.

With smaller conductors it is possible to use thinner paper but in at-

Fig. 3—A cross-section of the 1800-*pair cable shows how the eighteen units are formed into the final cable*

tempting to use paper thinner than used in the 1200-pair cable another difficulty arises. In wrapping the paper strip around the conductor in the manufacturing process, certain tension must be maintained and with too fragile a paper tearing is apt to

result. This difficulty was partly overcome by the Western Electric Company through improving its insulating machinery so that thinner paper could be satisfactorily used. It was thus possible to employ paper which was appreciably thinner than the two-and-one-half-mil paper of the earlier cable.

While all this work was going on another development had been made which changed the arrangement of the pairs of conductors inside the sheath. The basic unit of all telephone cables of this type is the pair: two conductors, each insulated with paper, twisted together. In practically all the earlier cables these pairs were laid up in concentric layers. Each layer was spiraled around the layer beneath it, and the direction of the spiral of successive layers was reversed. This gave a firm body that could be easily handled.

The new development built up small unit cables, each of 101 pairs for the 1818-pair cable, and then assembled these in a long spiral to form the complete cable. This new method brought about certain small savings due to a reduction in the take-up—or shortening of the effective length of the conductors due to stranding—and considerably simplified the manufacturing of the larger sizes of cable. It resulted in a more flexible core which is also important with the larger cables.

As a result of these various developments and improvements, an experimental cable was constructed with 1818 pairs of twenty-seven-gauge wire. Experiments in pulling this cable in and out of ducts indicated that a somewhat firmer core would be desirable. A cable of the same number of pairs but with twenty-six-gauge wire was then tried and found satisfactory. It is this cable that has now been standardized and will be used in the future in many of the large metropolitan areas and other places where conditions make it desirable.

In building up the new cable, two of the hundred-pair units are used as a center and around them are spiraled six other hundred-pair units. Around these are laid the remaining ten units to complete the full 1800 pairs. This may be seen in Figure 4, where the two inner groups point vertically upward, the next layer of six units points out at an angle of about forty-five degrees, and the outer layer of ten units is bent down.

Fig. 4—The arrangement of the eighteen units is here clearly evident

For convenience in identifying pairs for splicing, it is customary in all the larger cables to use several colors of paper to insulate different groups of pairs. In the 1200-pair cable, for example, the pairs in each group all have insulation of the same colors, which are different for adjacent groups. In

all, six colors are used. Each group is distributed over the whole or part of one or more of the annular layers, and the same color appears only in widely separated parts of the cable. In making a splice each group is bunched together and joined to the corresponding group of the continuing cable.

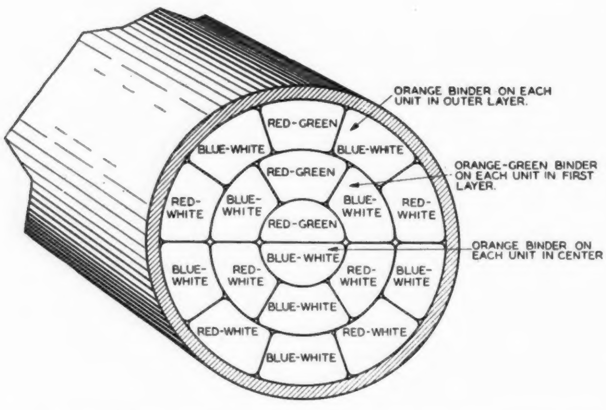


Fig. 5—The symmetry of the color arrangement of the hundred-pair units with reference to the three red-green groups makes identification of groups comparatively simple

This method is facilitated by the new construction, as the hundred pairs of a unit are all of the same color and already bunched. Each unit in addition is loosely bound with cotton threads, those of adjacent layers being of different colors, which makes it easier to identify corresponding units. A simplification of the color scheme has been developed which is indicated in Figure 5. The two wires of a pair are always insulated with differently colored paper and one of the two inner units uses red-green and the other blue-white paper. The next layer has one unit of red-green, and on each side of it a blue-white unit, followed by a red-white unit, and so on. The outer layer is similarly built up with one red-green unit and then alternately blue-white and red-white units. As a result the cable is symmetrical in appearance when looked at from each end so that locating corresponding units in making a splice in a manhole is a relatively simple matter.

At the termination of these cables in central offices it is customary, for convenience in distributing the pairs to the main frame, to splice them into several small cables with double silk and single cotton insulation. In

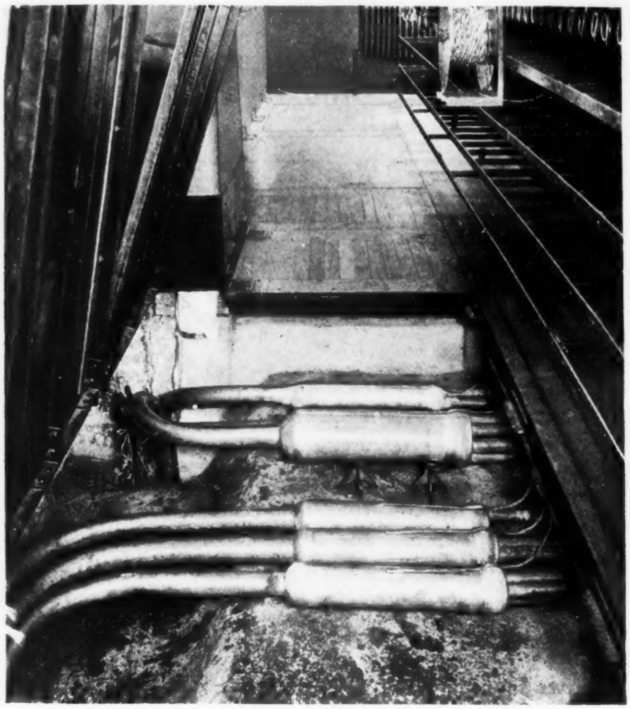


Fig. 6—The fourth cable from the bottom shows an 1800-pair cable spliced to nine 200-pair cables for distribution to the main frame

Figure 6 is shown such a splice where nine 200-pair are connected to one of the new 1800-cables. The 200-pair cables run under the floor for a few feet and then up the vertical side of the frame where they are fanned out and connected to terminal protector blocks. The amount of space required for fanning out one of the new cables can be seen in Figure 7. Each 200-pair cable requires about five feet of terminal strip so that nine rows of blocks, each about five feet high, are required in all. As a contrast a small piece of the 1800-pair cable is placed beside the terminal blocks.

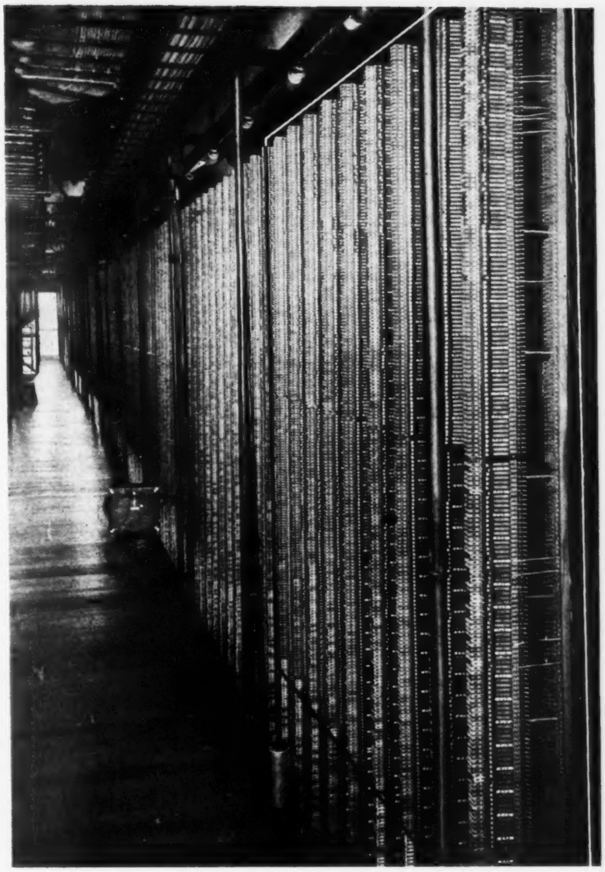


Fig. 7—Nine rows of terminal blocks—each about five feet high—are required to fan out an 1800-pair cable

These last two views were taken in the Cumberland Office of the New York Telephone Company in Brooklyn and show the termination of the first commercial installation of 1800-pair cable, which was completed in the spring of 1927. Since that time a limited amount of this cable has been manufactured on temporarily modified machinery. The Western Electric Company, however, has designed and is about to put into operation new and improved machinery in order that it may be in a position to take care of the demand that is expected for the new product.

Private Branch Exchanges

By R. W. HARPER
Systems Development Department

A CENTRAL office, functionally considered, is that part of a telephone system which connects any subscriber in the area served by it to any other in the same area, or which acts as the first of a chain of connecting centers when the subscriber called is at a more remote location. A private branch exchange serves a group of stations within a single establishment in a closely parallel manner. That there are 130,000 private branch exchanges in use in the Bell System is a striking fact which makes one realize the importance of this rapidly growing part of the telephone plant. In some of the larger cities P. B. X. attendants outnumber central-office operators; in Manhattan, for example, there are about 9500 central-office operators while the P. B. X. attendants number approximately twenty thousand.

Fig. 1—The 505 P. B. X. uses neither cords nor plugs; all switching is done by manipulating keys mounted on the face of the cabinet

In the very early days a single telephone in any one residence or place of business was ample. The telephone was so superior to former methods of communication, by mail or messenger, that its easy accessibility to each individual that might have occasion to use it never occurred to any one as being at all necessary. Nor did it seem necessary to have telephonic means of communication between persons within a single establishment—much smaller at that time than are some of our gigantic corporations now. As the telephone came to be used more and more, however, and as greater numbers of employees in every office or factory found occasion to take advantage of its time-saving possibilities, a demand naturally arose for more than one station in the larger establishments. There arose also a need for the telephone for intercommunication; a bookkeeper in the office found much time and energy could be saved if he could talk directly with a clerk in the shipping room. Out of these demands arose the private branch exchange, or P. B. X. as it is colloquially termed, a private central office serving directly its own stations.

A P. B. X. was not, of course, the

Fig. 2—A large 604-type P. B. X. installed in Bell Telephone Laboratories

only solution possible. There could have been the same multiplicity of stations within the establishment and the same possibility of intercommunication, had each station had its own line to the main central office and its own number. Any station could have called another by passing through the central office operator, and so far as the members of the organization were concerned there would have been little difference except that the station designation numbers might have been longer.

From the standpoint of some one calling in from the outside, however, there is a considerable difference. The outsider often does not know the name of the person he wants to talk to; he knows what he wants to find out or what knowledge he wants to impart but that is all. If for any establishment there were only a long list of names and numbers in the directory he would be helpless. Obviously the only satisfactory solution is to have but a single number for any one establishment and a single person—or, for the larger concerns, a single group of persons—to answer all incoming calls. This person, the P. B. X. attendant, with intimate knowledge of the organization could connect the incoming call to the station that could most effectively deal with it. Thus the need for an attendant was paramount in calling the P. B. X. into existance and the attendant is still of primary importance to the modern P. B. X. system.

If there are fifty telephone stations in the local establishment they will never all want to talk with the outside simultaneously. At any one time some stations will not be in use at all and some may be talking to other local stations, leaving only a small remainder making demands for outside service. The ratio of central-office trunks to stations, therefore, is always less than unity although it varies over a considerable range depending

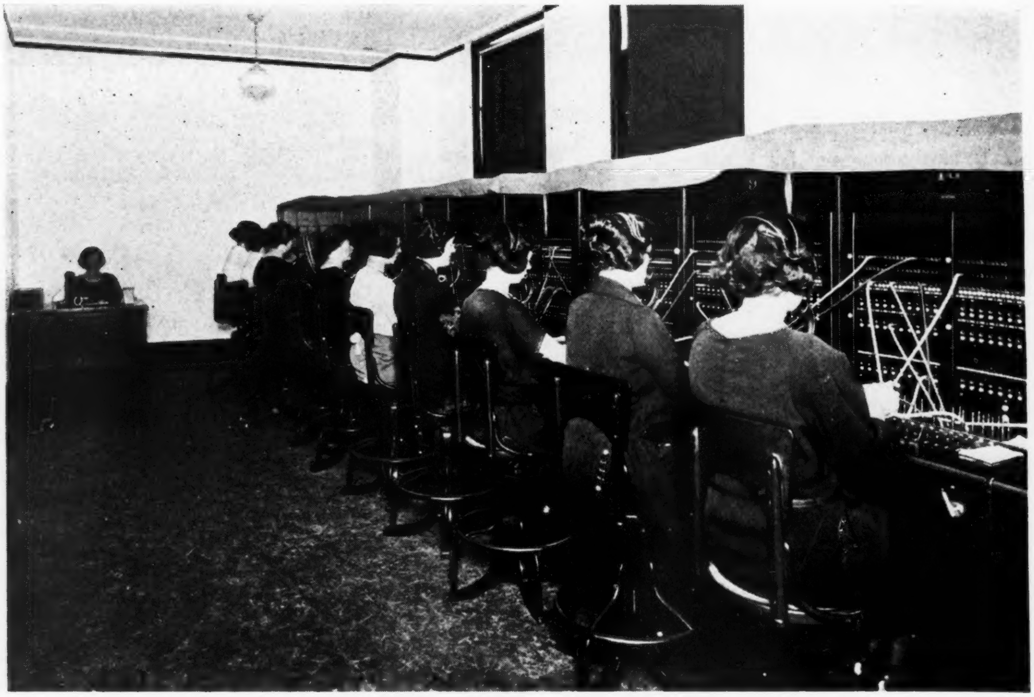


Fig. 3—A medium sized P. B. X. of the manual type is the 600-*C*

on the type of business. The attendant and the P. B. X., of course, always partially, and occasionally entirely, offset the savings due to the reduction in number of trunks. The attendant, however, performs so many useful services that she is generally regarded as an asset rather than an expense.

Differences in types of business as well as differences in size naturally affect the P. B. X. equipment furnished for the subscriber. In some organizations most of the calling is between members within the organization, whereas in others practically no local calls are made. In some places conditions favor dial service while in others the manual system offers certain advantages. Differences in the number of stations to be served necessarily make a difference in the type of P. B. X. furnished. Thirty-five varieties of P. B. X. have been made in the past and probably more will be built in the future as methods of doing business change and as telephone apparatus and equipment improve. There has never been this number in standard use, however, at any one time. At present only six types are standard and stocked and this number probably fairly represents the number standardized at any one time in the past.

In the manual class the range of size varies from the small 505 type, with a maximum of seven stations and three central-office trunks, to the large 604-C which, as used by the Consolidated Gas Company of New York, has 1650 station lines, 221 trunks to central offices, and 175 tie lines to other branch exchanges, and requires 42 attendants during the busy part of the day.

The small 505-type board uses no cords or plugs but all connections are made by keys on the front of the board. It is so small that it can be

placed on an ordinary desk, and may be operated by a clerk who may also have other duties. Contrasting with this the larger exchanges, such as the one in our own Laboratories, have all the appearance of a central office. Between these extremes are other types and sizes such as the 550* and the 600-C.

Each type of board is made necessary by the conditions of service that it has to meet and by the number of lines that it must serve. The cordless 505 type is compact and seems very simple but actually would become difficult to operate if the number of lines were increased to any great extent. To locate an operated key from the large number all exactly alike becomes somewhat trying. A cord plugged into a jack, on the other hand, is easy to see and so as the number of lines increases better results are secured with cords.

The No. 1 and No. 2 intercommunicating sets, which do not require attendants for local calls, are interesting because of their small size. Lines run from each station to every other, and each station is in reality its own P. B. X. as a key is depressed corresponding to the line wanted and no other switching equipment is required. Except for this very small unit, private branch exchanges not requiring an attendant for local calls have been designated for the larger installations only. The present standards are the 700 and the 740** dial-types, the former of which may have any capacity up to one approaching that of a central office. Both of these boards may dial an outside number without the aid of the local attendant. The 740-A, only recently developed, has a maximum capacity of eighty-eight station lines and will serve subscribers with a smaller number of local stations.

There is a large and increasing demand for tie-line intercommunication between P. B. X.'s. Large organizations, such as public service companies, often have a number of private branch exchanges located at different points throughout the city. The tie-lines may be arranged for dial or manual service, depending upon the type of P. B. X. and the requirements of the subscribers. When tie-lines are provided between dial P. B. X.'s the circuits can be arranged, if desired, so that a station in one P. B. X. can dial any station in another. At Bell Laboratories there are direct tie-lines to and from nine other Bell System P. B. X.'s in and around New York City.

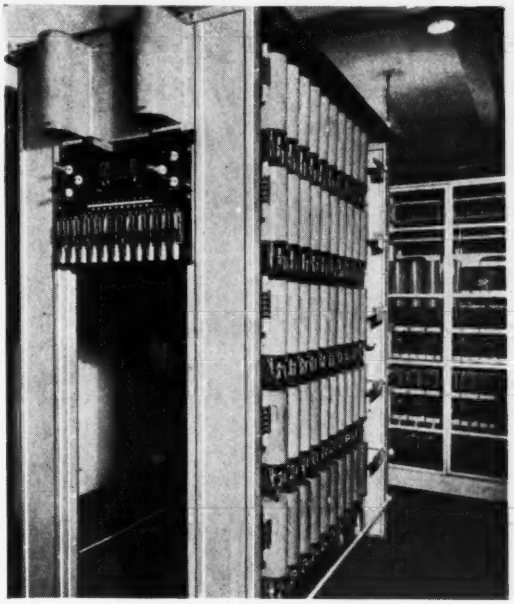


Fig. 4—Dial-type private branch exchanges have usually been made in the larger sizes as indicated by this section of a 700 type

* *The latest design of this type, known as the 551, is described in* Bell Laboratories Record *for July, 1928.*

** *Described in* Bell Laboratories Record *for August, 1928.*

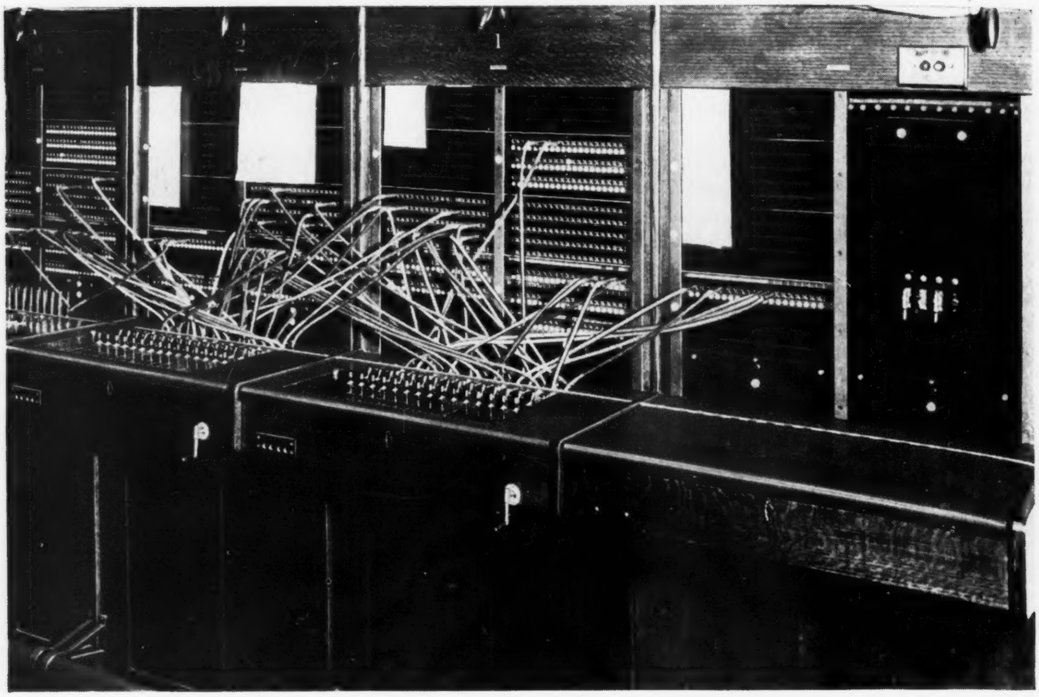


Fig. 5—A P. B. X. of the dial type as a rule has a group of manual positions for the answering of incoming calls. The above is a part of a 700 P. B. X.

Of the 115,000 P. B. X.'s manufactured by the Western Electric Company during the period from 1910 to 1926, 96% were of the small sizes. Of these 9% were of the No. 2 and No. 4 types, the latter of which is now no longer standard, the other 87% being about equally divided between the 505 and the 550 types. Naturally, there are fewer of the very large boards so it is not surprising that in this same period only a score or more of these have been manufactured, although additional sections are being made continually to take care of the expansion of the existing boards. These figures make it easier to understand that in some central offices in the business section of New York City approximately seventy-five per cent of the total working lines terminate in private branch exchanges.

Atomic Physics and Circuit Theory

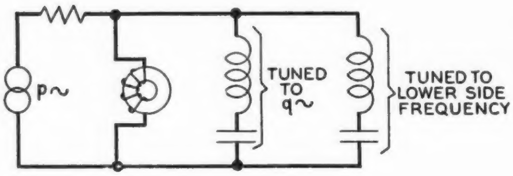
By EUGENE PETERSON
Research Department

IT has recently been suggested by R. V. L. Hartley that there appears to be a similarity between some of the phenomena observed in atomic physics and those found in certain non-linear electrical circuits. This idea is interesting and very important since it suggests the possibility of accounting on purely classical grounds for the methods used in calculating quantum phenomena. The non-linear circuits of interest here are of the variable reactance type such as the magnetic modulator for variable inductance, and the condenser transmitter for variable capacitance.

A number of years ago some of us in the Research Laboratory were working on magnetic modulator circuits to check theoretical speculations which were of considerable interest at that time. All modulators have this feature in common, that they distort the wave shape impressed upon them: a process which yields new frequencies related to those originally impressed on the circuit. If for example a pure sine-wave generator is connected to the modulator, then the new frequencies produced are harmonics, integral multiples, of the generator frequency. When two of these generators of different frequency are connected to the modulator (they may be the carrier and voice waves of the ordinary radio broadcast transmitter) we get, in addition to the harmonics of each of the generator frequencies, combinations between them, among which are the sum and the difference of the two original frequencies. The latter are known as side frequencies; they are evidently produced by the wave-distorting or non-linear properties of the modulator, since these new frequencies do not arise when ordinary non-distorting elements make up the circuit. In the magnetic modulator the non-linearity is provided by the magnetization characteristic when sufficiently large magnetizing forces are used.

The problems arising in modulator circuits are those concerning the relationship of these new current components to the original ones. Two of the properties of the modulator which are of interest in this connection are the stability, and the ratio of the side-frequency power developed to the signal power supplied; usually the latter is termed the modulating gain. In the first magnetic modulator circuit set up, we had three filters connected to the modulating coil: one to supply the carrier, the next to supply the signal, and the last to take off one of the side-frequencies to a load circuit. Even at the most favorable value of carrier voltage, the modulating gain was found to be too low with our hastily improvised arrangement and we set about the construction of a more efficient circuit. To do this the modulator coil was built up with very thin laminations of permalloy, and

the number of turns and the size of the coil were adjusted to draw maximum power from the two connected generators. When these changes were gradually incorporated in the circuit, the modulating gain rose until finally a curious phenomenon was noticed by E. T. Burton: the circuit became unstable, and a number of new frequencies were produced which apparently bore no relation to the



Circuit for the production of low-frequency oscillations. Current from the carrier frequency (p) generator, applied to the toroidal coil yields simultaneously a low frequency (q) current and the side-frequencies. A tuned circuit is provided for only one side-frequency — the lower

originally impressed frequency. These were made evident by a mushy note which was heard when a telephone receiver was connected in circuit. This effect obviously set a limit to the gain which could be usefully obtained and it seemed desirable to establish the reasons for its appearance.

The effects are more easily followed when we use simple tuned circuits instead of filters. In that case single frequencies are generated rather than the large number of frequencies which appeared in the filter circuit and gave rise to the mushy note observed. An approximate mathematical analysis of this simplified circuit was made. Assuming a magnetic core free from hysteresis and working under simple circuit conditions, it was found that the flow of the two side-frequencies changed the coil resistance to the two input frequencies. In the path of the higher impressed frequency p this resistance was positive; in the path of the lower impressed frequency q the resistance introduced by the flow of the upper side-frequency was positive but the resistance introduced by the flow of the lower side-frequency was negative. These conclusions were in complete agreement with those which had been found theoretically by Mr. Hartley in 1917, and which he had also obtained somewhat later in the case of a condenser transmitter. These conclusions are carried over unchanged to the higher order side-frequencies such as $2p \pm q$ and $3p \pm q$.

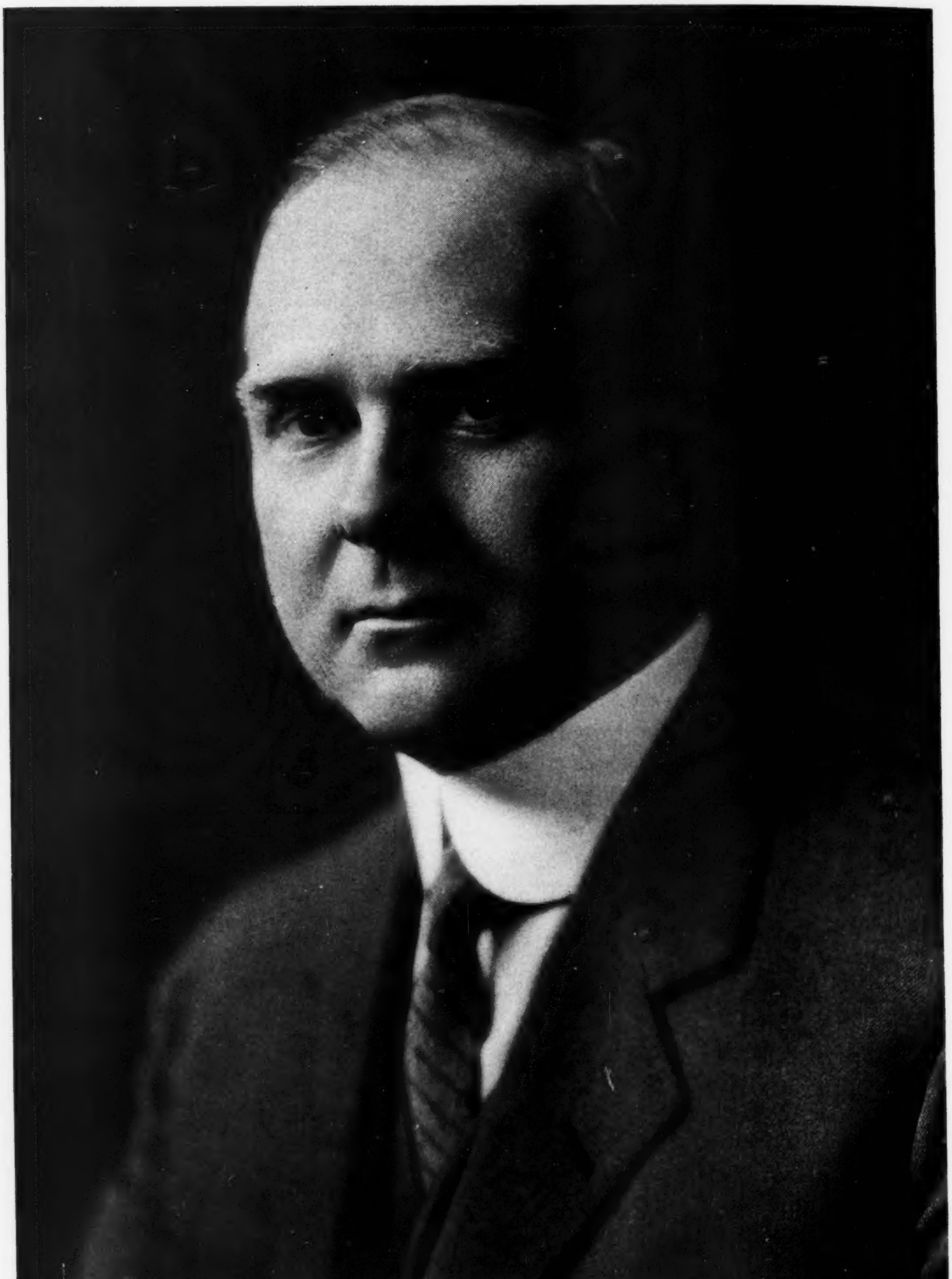
This idea of negative resistance enabled us to account for the experimental observation in a qualitative way at least, and justified the initial assumption that the non-linear magnetic characteristic, and not the hysteresis loop, was responsible for the effects. For if the upper side-frequency meets a high circuit impedance, so that the resulting current is small, and if the lower side-frequency meets a low circuit impedance, so that the resulting current is large, then the net effect of these two currents on the resistance to q will be negative. When this net effect, which depends upon the carrier amplitude, is great enough to make the total circuit resistance negative, and when the circuit reactances are nearly annulled, then oscillations will result and if the generator of frequency q be withdrawn, this frequency, together with its side-frequencies, will be sustained. It was with the simpler circuit shown that the theoretical conclusions were more definitely tested and found to be in general agreement. In order that sustained frequencies might arise the carrier was required to exceed a defi-

nite amplitude, the associated circuits were required to be fairly well tuned to the two frequencies involved and the resistances of the tuned circuits were required to be sufficiently small. In a circuit using filters these conditions are obeyed at a number of frequencies so that several currents are sustained.

To sum up these effects we may employ terms ordinarily used of regenerative vacuum-tube circuits, in which oscillation is produced by feeding current from the plate to the grid circuit in proper phase. The source of energy here is the plate battery, whereas in the magnetic modulator it is the carrier generator. For each, there is a critical value below which sustained oscillations cannot exist. Further, in the magnetic modulator case there is not merely one sustained oscillation, but at least two, which we have designated q and p-q. Neither can be sustained without the other, and if we introduce sufficient resistance to either q or p-q, or if we introduce sufficient reactance to either circuit both oscillations cease.

Mr. Hartley has suggested in a paper presented before the American Physical Society on December 29, 1928 that there is a striking resemblance between the phenomenon just described and the Raman effect in atomic physics. Raman found that in passing light of a definite spectral composition through certain liquids, the spectral composition of the emerging light was changed. New lines appeared, sometimes as pairs equally spaced above and below a line in the spectrum of the incident light, with the higher frequency line always weaker than the lower. In some cases only the lower frequency line was strong enough to be observed. Further, the interval between the new lines and the original lines from which they were displaced has been associated with a line in the absorption spectrum of the liquid; that is, the interval has been associated with a molecular resonance. To press the analogy with the modulator circuit, the frequency of the incident light corresponds to the supply frequency p, the molecular resonance frequency is q, the stronger observed line is the lower side-frequency p-q, and the weaker is the upper side-frequency $p+q$. The parallel is even more striking in the case of the condenser transmitter, in which the same type of effect occurs, and in which, moreover, the power involved is proportional to the frequency. This is suggestive of the quantum relation.

The importance of Mr. Hartley's suggestion lies not only in its application to the Raman effect but also in its application to the general field of atomic physics. The present effort in atomic physics is devoted to discovering methods such as matrix mechanics by which the observed effects may be computed, and the results are in many cases in excellent agreement with the facts. However, there does exist some question as to the physical significance of the quantities employed in these non-classical methods of computation. Following Mr. Hartley's suggestion it may be possible to compute these effects by treating non-linear mechanisms by ordinary mathematical means. If this should prove feasible a physical interpretation would be provided for quantum mechanics, and we should then have a classical mechanism capable of reproducing quantum phenomena.



HARRY PRESCOTT CHARLESWORTH

Entered American Telephone and Telegraph Company, Engineering Department, 1905; *Equipment and Transmission Engineer,* 1919; *Plant Engineer,* 1920; *Vice-President Bell Telephone Laboratories,* 1928

Harry Prescott Charlesworth

ON December twenty-seventh, Harry Prescott Charlesworth was elected Vice-President of the Laboratories. He will be in charge of its operations during Mr. Craft's absence.

After graduation by the Massachusetts Institute of Technology in 1905, Mr. Charlesworth entered the Engineering Department of the American Telephone and Telegraph Company, which was then located in Boston, and in connection with which one of the development and research laboratories of the Bell System was operated.

His first assignment was to the development of local and toll circuits and associated apparatus. In this work he was engaged for two years, until in 1907 the American Company moved to New York City.

During the next ten years Mr. Charlesworth was active in the development of toll operating methods and the general related engineering problems involved in extending and improving telephone service.

With the opening of the war he was specially assigned, as a result of his broad knowledge of telephone plant and its operations, to handle problems wherein the Bell System could be of assistance to the Government in the national emergency. In this capacity he was throughout the war active on communication facilities for army camps, naval bases, supply depots and particularly for the Government Departments at Washington, where he also rendered continuous assistance to the Telephone Company on general equipment and traffic engineering matters.

At the close of the war he took up dial-system development work and with the creation of the Department of Operation and Engineering, was appointed Equipment and Transmission Engineer under Vice-President Gherardi. A year later he became Plant Engineer of that Department, in which position he has been concerned with all phases of the engineering of the telephone plant and with relations with other wire-using companies.

Thus, throughout his telephone career of almost a quarter of a century, Mr. Charlesworth has taken an active interest in the development of telephone apparatus and equipment to meet telephone needs, and in the origination of proper operating methods for handling telephone traffic. His background of scientific training and long contact with the development and operating problems, and his proven ability to coordinate and advance the work of others, have resulted in constantly increasing responsibilities in the Bell System. And now with an experience well rounded by his supervision of plant engineering in general, he returns to his original interest in development by assuming leadership of the Bell Telephone Laboratories.

Development of Step-by-Step Line Finders

By W. L. DODGE
Systems Development Department

IN the early step-by-step exchanges a selector was provided for each subscriber's line. It made the first of a series of successive selections resulting in a connection to the line called. Selectors, however, are comparatively expensive mechanisms, and as they are in use only when the line is making an outward call a much smaller number of them would meet the requirements could some method be devised of connecting them to a line only while an outward call was being made. To the search for the most efficient method of doing this, much thought has been given and many studies made which, embodying themselves in laboratory development, have resulted in the step-by-step line finder. Although the mechanism itself is of the step-by-step type, the function it performs owes its inception to the panel system, a later development of the dial-system method of telephone switching.

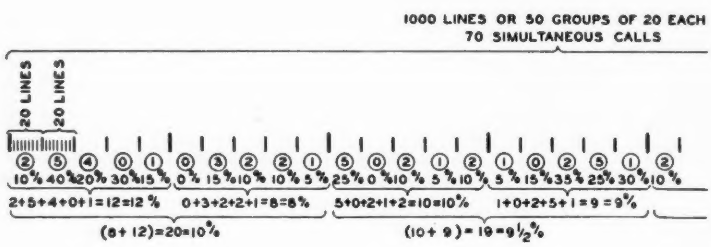


Fig. 1—Diagrammatic representation of the advantages from greater mutuality between selectors and lines

The first step toward the more economical use of selectors was the introduction of the Keith or plunger-type line switch in 1907. This is a comparatively inexpensive switch one of which is connected to each subscriber's line. It starts operating as the subscriber lifts the receiver from the hook and completes a connection to one of a group of ten trunks leading to selectors before dialing is begun. Line switches of a large number of lines (the exact number being dependent on traffic conditions) have access to the same group of ten trunks with the result that the number of selectors is much smaller than the total number of lines.

The possible reduction in selectors depends for the most part on the number that may be reached by any one line, or conversely, on the number of lines that may be reached by any one selector. The smallest number of selectors that will give satisfactory service is fixed by the number of calls being placed at one time but only if each selector had access to all the lines could this lower limit be reached. With a lesser degree of accessibility the chance distribution of calls enters to require a greater number.

Consider for example a small central-office of one thousand lines over which a maximum of seventy outgo-

ing calls are made at any one time. As an initial assumption let each selector have access to twenty lines so that the thousand lines in the office may be divided into fifty groups of twenty lines, each group being served by a certain number of selectors. The seventy outgoing calls being made simultaneously will not, of course, be equally divided among these groups. Chance affects the distribution so that some groups will have more and others less than the average number. A possible distribution is indicated on Figure 1 in numbers written under each group. With this distribution and assuming that the number of selectors is to be so chosen that all outgoing calls can be handled immediately, there must be—in the case given—five selectors serving each group as that is the maximum number of calls occurring at the same time in any one group. The minimum number of selectors possible—seventy for the thousand lines if there were complete accessibility—is seven per cent of the number of lines while with the arrangement indicated, where each selector has access to only twenty lines, the selectors are twenty-five per cent of the number of lines.

In grouping lines an effort is always made to obtain a balance by so sorting the lines with lower or higher calling rates among the groups, that the average and peak calling rate for all groups is the same. Over a period of time, therefore, all groups will have had at one time or another the same number of simultaneous calls. The diversity indicated on Figure 1 is only that existing at any one moment. A few minutes later the grouping probably would be entirely different, with a group now having no calls perhaps then having five, and this shifting of calls would extend on through the larger groupings.

Increasing the accessibility by making each set include one hundred lines, indicated by the brackets on the dia-

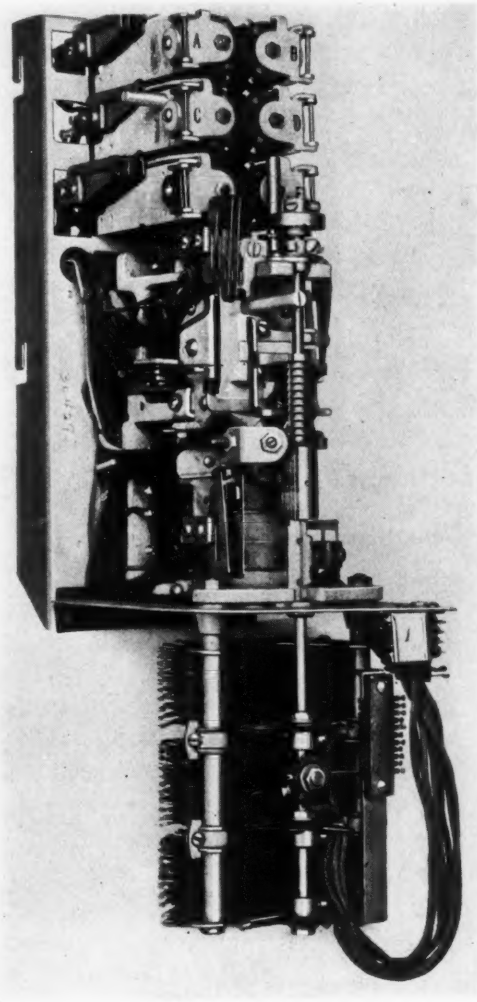


Fig 2—A step-by-step line finder showing its three banks. The commutator at the right between the middle and upper banks forms part of the vertical hunting circuit

gram, reduces the ratio of selectors to lines to twelve per cent. If the increase of accessibility is carried to two hundred lines the ratio of selectors to lines may be lowered to ten per cent. The actual possible decrease in selec-

tors with increase in accessibility is derived from somewhat intricate probability calculations based on such assumptions as the average duration of a call, and the calling rate, and probably would not, in any particular case, fit the figures given in the illustration. These are arbitrarily picked merely to bring out the possible reduction in selectors due to the effect of chance distribution and greater accessibility.

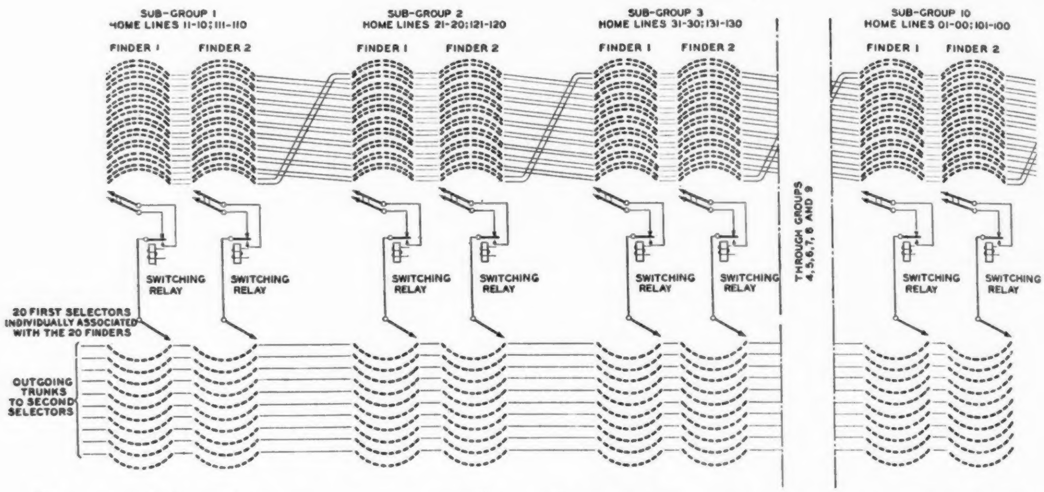


Fig. 3—Schematic arrangement of lines, line finders, and selectors for a unit of 200 subscribers

In this example only the matter of mutual accessibility has been mentioned; the method of obtaining this accessibility in practice has not been brought in. Actually there are two methods in general use as has already been indicated: by line switches, or by line finders. It was natural that the line switch should have been developed first because it accomplished a considerable reduction in the number of selectors with a simple mechanism and a minimum number of terminals over which hunting would have to be done. Without either line switches or line finders the ratio of selectors to lines is, of course, one hundred per cent, but the use of a line switch hunting over five trunks to selectors would reduce this figure, for example given in Figure 1, to twenty-five per cent. In this case a group of twenty lines would be arranged to be served by five selectors.

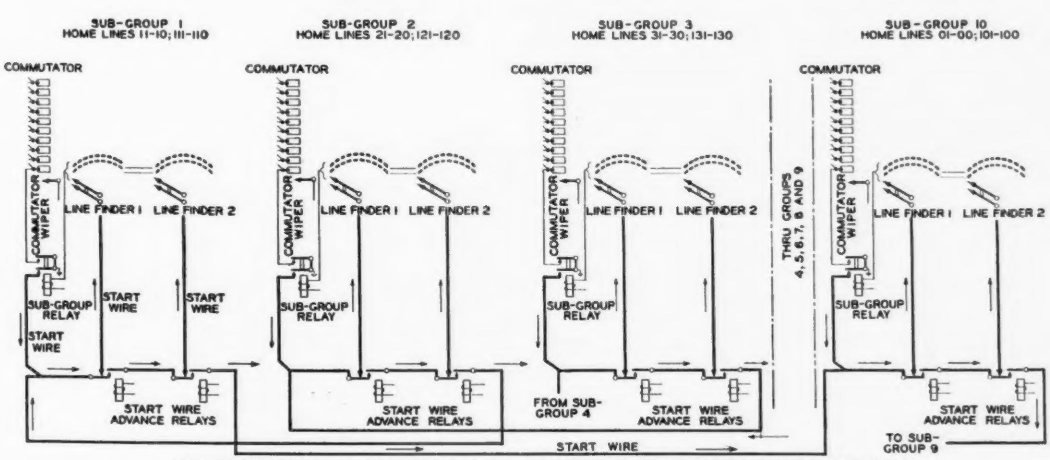
The reduction of selectors can be carried further, of course, by arranging the line switches so that they can hunt over a greater number of trunks. Based on the data of Figure 1, a line switch hunting over nineteen trunks would reduce the ratio of selectors to lines to nine and one-half per cent. The line switch method of obtaining accessibility, however, becomes expensive when it is attempted to obtain a large degree of accessibility. A switch is required for each line and every increase made in the number of trunks over which the switch will hunt means an increased cost which is multiplied by the number of lines. Development in the Bell System has been along the line of the alternative method of obtaining accessibility by use of a line finder. With this method the finding process is reversed; instead of

having the lines hunt for an idle selector, the selectors are made to search for the calling line. A line finder is provided for each selector so that each reduction in the number of selectors brings a like reduction in the number of line finders. This proves to be a more satisfactory way, from an operating standpoint, of solving the problem.

To obtain the same reduction in selectors, however, the wipers of a line finder must have access to many more contacts than those of the line switches. When the ratio of selectors to lines is twenty-five per cent, for example, each of the 250 line finders would require access to twenty lines whereas had line switches been used each of the thousand would have required access to only five trunks to selectors. It is desirable to have the hunting done between the instant the receiver is lifted from the hook and the time the subscriber is ready to dial so that the difficulty is not so much in actually hunting over a larger number of contacts as in accomplishing it in this short time. The manner in which this rather difficult feat is accomplished will be clearer after the line finder itself has been described.

As a basis for the step-by-step line finder there was available the standard step-by-step mechanism out of which the selectors and connectors are made. Its contacts are arranged in two banks, each having ten levels with ten contact positions arranged around a section of circular arc. A pair of wipers for each bank, by suitable relays and mechanisms, can be moved up one level at a time and then rotated around the arc to any one of the ten positions. The movement is always step-by-step, that is, up one level at a time or around one contact position at a time, which gives the name to the complete system of switching.

As it was originally used this switch had access to one hundred lines. Four contacts were available for each line, the two banks each of one hundred pairs of contacts just making up this number. In the more recent systems each line requires only three contacts so that by adding a third bank to the switch six hundred contacts, or two hundred lines, become available. An



THE GROUP RELAYS ARE CONTROLLED BY THE LINE CIRCUITS OF THE HOME LINES WHICH ARE SHOWN IN THE FIRST LEVEL OF THE BANKS.

Fig. 4—Schematic arrangement of sub-group relays, commutators, and start wires

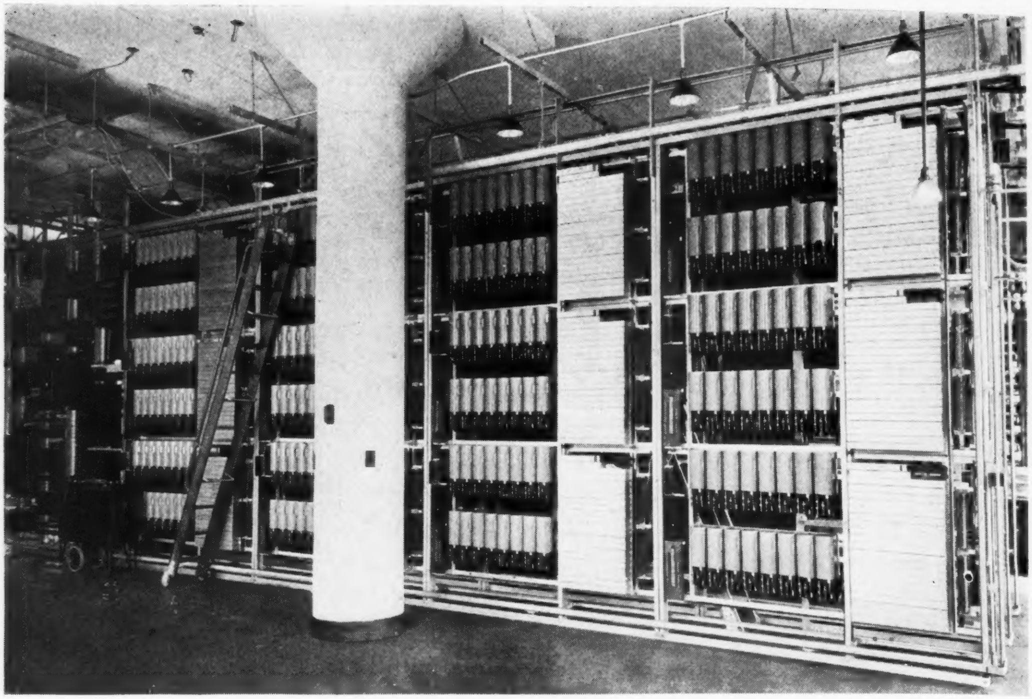


Fig. 5—Line-finder frames in a central office. Each group of two hundred lines has only sixteen line finders associated with it

accessibility of two hundred lines was deemed sufficient to reduce the number of selectors to a satisfactory total and the switch thus developed is shown in Figure 2.

Although this switch gives access to two hundred lines there are only one hundred stopping positions of the brush, ten rotational positions on each of the ten levels. Which line is chosen of the two that terminate in each position depends on the action of relays associated with the switch. If one of the pair of lines running to a brush position were in use and a call should come in on the other, another of the finders serving that group would "hunt" for it, as the two hundred lines running to any finder are multipled to each of the other finders serving that particular two hundred lines.

In order to hold the average hunting time of the finder to a minimum each group of two hundred lines is divided into ten sub-groups of twenty lines, and each of these sub-groups appears on the lowest level of one or more of the line-finder banks, and constitutes the "home lines" for these finders. This same sub-group of lines appears in the second level of another set of line finders, in the third level of another set, and so on. The line finder "start" circuit is so arranged that when a call originates, one of the line finders that has the calling line among its "home lines" begins to hunt for it. If these particular finders were busy the start lead would be transferred to the finders having the calling line in their second level, and if these in turn were busy, to the finders with the line in their third level, and so on. In this way minimum hunting time is required for each call. The manner in which the lines are mul-

tipled to the different finders and the way in which the start lead is transferred from one to another may be understood by a study of Figures 3 and 4.

These two-hundred-point line finders, a typical installation of which is shown in Figure 5, have now been in use for some time. In the installation illustrated, three groups of finders, each group serving two hundred lines, are mounted in a vertical frame. The line and cut-off relays are arranged at the right of the line finders.

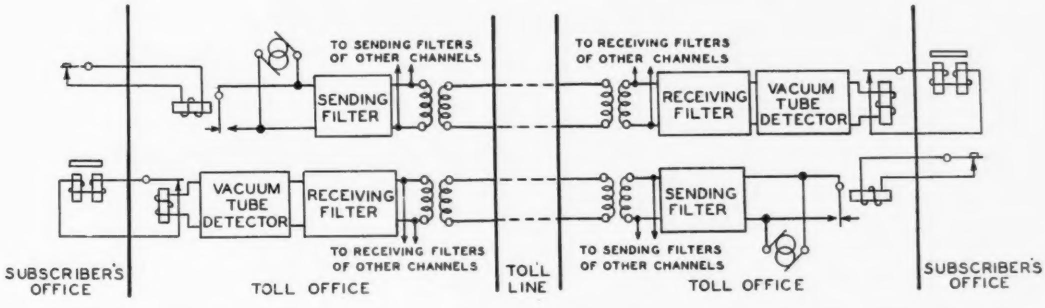
The development of the line finder to replace the line switches illustrates a trend, noticeable in other Bell System developments of dial apparatus, to replace a large number of small mechanisms by a smaller number of more inclusive ones. This results in fewer pieces of equipment to maintain and opens the way to still better service to the subscriber.

New Equipment for Voice-Frequency Telegraphy

By J. A. MAHONEY
Systems Development Department

ONE of the telegraph systems being used to a steadily increasing degree on Bell System lines is that which provides facilities for transmitting, over a four-wire circuit, twelve messages simultaneously in each direction by means of currents in the voice-frequency range. It is used almost entirely for "leased wire" service between subscribers in distant cities who, employing their own operators, have the channels available for continuous service. A simplified form of the necessary apparatus is now available, retaining the electrical characteristics of the older assembly but introducing an improvement in compactness and convenience.

By the use of carrier currents in a frequency range approximating that of the voice currents of telephone conversations, the system has been made suitable for a toll plant designed primarily for telephone transmission. At intermediate points the complex current conveying all the telegraph messages is amplified by ordinary



Carrier-telegraph apparatus for a single two-way channel, connected to a toll line

four-wire telephone repeaters. The essential elements of the system are a generator for producing the carrier currents; relays for controlling their transmission in accordance with a telegraph code; filters for separating the different frequencies, combined for transmission over the line; and vacuum-tubes for rectifying each of the separated alternating currents into direct current for operating the telegraph receiving apparatus. Terminal apparatus embodying these units, connected at each end of a toll line, make it a path for telegraph messages rather than for conversations.

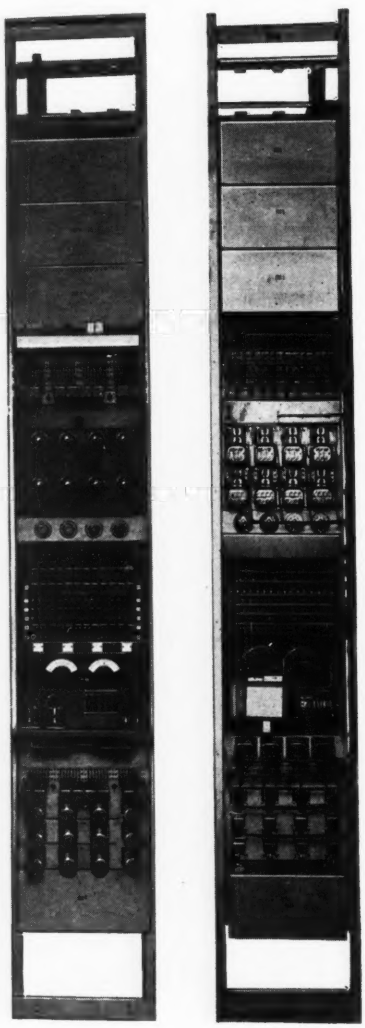


Fig. 1—Front and rear views of the new bay, containing four channel terminals

For each of the two-way channels, and so for the current of each frequency, a group of apparatus known as a channel terminal is provided at each terminal office, to translate between the alternating-current line signals and the direct-current impulses of the subscriber's sending and receiving apparatus. The group of terminals associated for service over the same toll line, twelve or less in number, make up a system terminal.

In the schematic the circuit arrangement is shown. Operation of a subscriber's key, or automatic transmitter, controls direct current through the windings of the sending relay, which in turn controls the alternating current passing onto the line. During spacing signals this relay short-circuits the alternating current, and during marking signals allows it to flow through the sending filter to the line. At the incoming end, the receiving filter of each channel terminal selects the proper current, which is amplified and rectified by the vacuum tubes of the detector circuit. The rectified current operates the receiving relay, which in turn controls the receiving subscriber's sounder or printer.

While messages are passing in one direction on one pair of the toll circuit, other messages are going in the opposite direction over the other pair. A subscriber wanting simultaneous service in both directions has two circuits between his establishment and the toll office. That arrangement, known as "full duplex" operation, is the one shown on the circuit sketch. For "half duplex" service, in which messages in opposite directions may

be sent as desired, but not simultaneously, only one circuit is required between the subscriber's premises and the toll office, but a one-way carrier channel is needed in each direction.

An important operating feature of the terminal equipment is the provision made for monitoring. An attendant at the central office must be able to observe operation of the circuits to be sure that everything is in good order, and must communicate with the subscribers' operators from time to time, in emergencies as well as about routine matters. The circuit sketch shows the sounders and meters by which operation can be observed, and the telegraph key by which the attendant can take control of the circuit. It is important that the monitoring apparatus be as convenient as possible, since many of the telegraph channels are used by financial houses in whose service interruptions or delays might be costly. Following then-current telegraph practice, the original voice-frequency equipment had monitoring apparatus permanently connected to each channel terminal, although it was not possible for the attendants to give their oversight to more than a few repeaters at a time. Since experience has shown that adequate supervision can be maintained with fewer sets of monitoring apparatus, in the new form of equipment only one set has been provided for each four channel terminals.

This use of common monitoring equipment, connected into any circuit at will by jacks, plugs and cords, has been greatly facilitated by the convenient location of the apparatus involved. It will be noted from the photographs that like pieces of apparatus have been grouped on mounting plates especially designed for them. At the top of each bay are plates bearing retardation coils, condensers, resistances and other minor elements normally requiring no attention; the telegraph relays, which need occasional maintenance, are located near the bottom; and the central portion of the bay is left clear for the apparatus used in controlling the repeaters. An improvement is thus realized over the method of mounting both fixed and adjustable apparatus for a particular circuit on one panel,

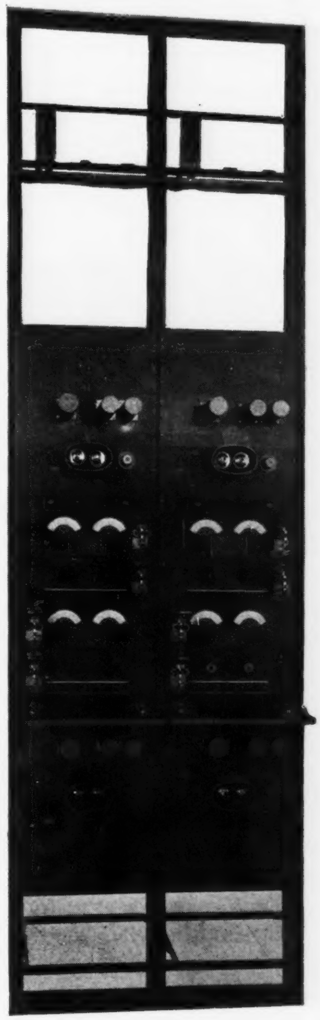
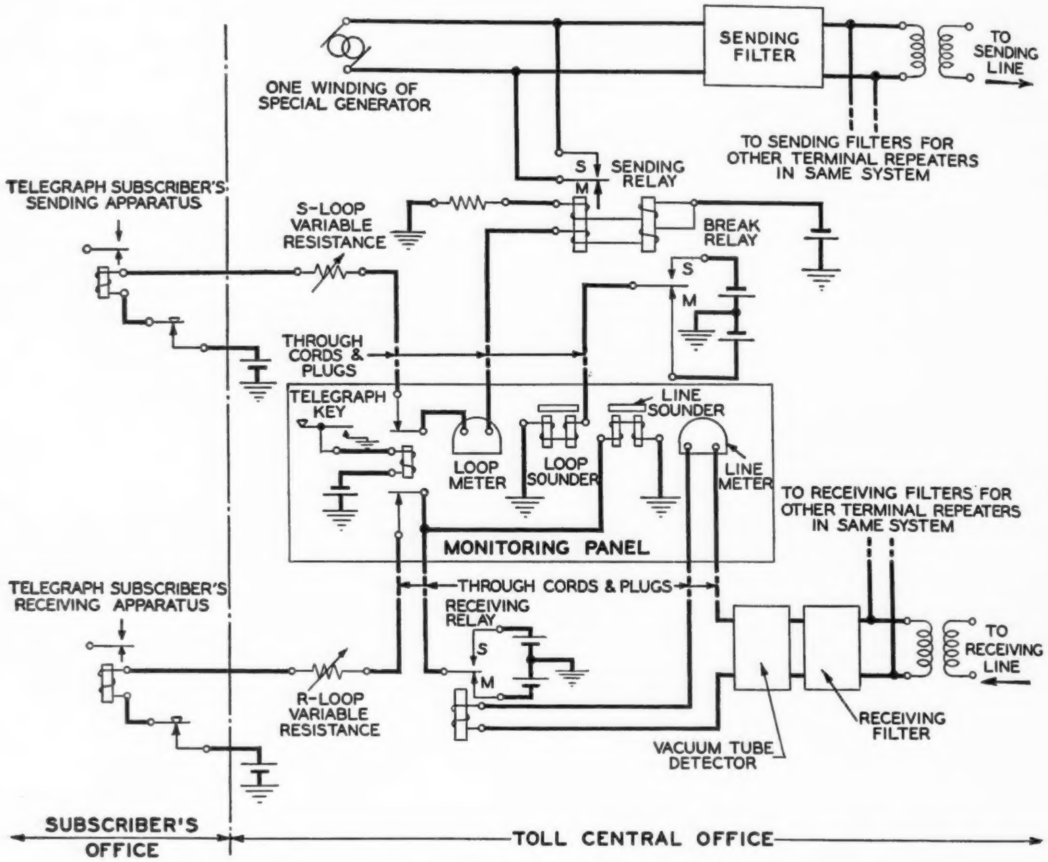


Fig. 2—Two bays of panel-mounted terminal equipment, equivalent to a single bay new equipment

which of course could not be located at the most convenient part of the bay for all the circuits.

Mounting most of the apparatus on standard mounting plates has made the bay rather than the panel graph relays and the receiving potentiometers, there are exactly four units of apparatus, one for each of the channel terminals. Where there are several units for each circuit on one of the plates, as in the case of the



A channel terminal and associated subscriber's apparatus arranged for full duplex operation and with the monitoring panel connected

the unit of equipment. Apparatus for four channel terminals and one monitoring panel are normally assembled on a channel-iron rack, and are wired in a single local cable. In contrast, the older panel-mounted equipment required a complete bay for two channel terminals and the two monitoring panels associated with them. On many of the mounting plates in the new bays, such as those for the tele- resistances and keys, these have been arranged in four separate groups. The only exception to the sub-grouping on the mounting plates, aside from the monitoring panel, is the filters; each of these is assembled complete on an individual plate. As a result the bay is divided in a general way into four vertical groups, each constituting a channel terminal. Ordinarily the bays will be lined up in

groups of three, the number required for twelve channels in each direction.

The advantages of this type of mounting are apparent in Figure 1. Any particular piece of apparatus is located in the same position in the bay for every repeater, a feature especially important for the circuit elements requiring attention—the jacks, keys and potentiometers. Convenience also follows on the wiring side of the bays from the arrangement, as well as from the accessibility of the terminals of all the apparatus.

Along with the improved assembly, simpler types of apparatus have been introduced. In the older terminal repeater, an expensive forty-step rheostat was used for the variable resistance in series with the subscriber's loop. This has been replaced by a series of flat-type resistances having values of fifty ohms, one hundred ohms, two hundred ohms, and so on up to eight hundred ohms, each of which can be short-circuited by a push-button key. Any value of resistance from fifty ohms to the total can be secured, in steps of fifty ohms, by operation of the proper combination of keys, with five or six resistances taking the place of the forty used in the rheostat. The key combination is a little less convenient to adjust, but since the adjustment is changed only when the repeater is connected to a new subscriber, this disadvantage is slight, and is more than offset by the greater ruggedness and reliability of the newer, simpler apparatus.

In the Bell System plant, voice-frequency telegraph systems are in use along the main toll cables, with a total of about 170,000 miles of two-way channels in operation on October 1, 1928. There were at that time thirty-three systems in service, the longest being from New York to Chicago, a distance of 884 miles. These systems form a network together with the open-wire high-frequency telegraph systems, which touches almost every important city in the country, and is an important factor in maintaining the highest grade of telegraph service now offered — telephone typewriter service at sixty words per minute in each direction. Combining the advantages of reliability and simplicity with savings in first cost and floor space, the new equipment will promote further the use of such facilities, thereby helping to secure the most productive use of the toll cables.

Ringing Machines for Small Offices

By R. D. de KAY
Systems Development Department

THE problem of an economical source of ringing current for the smaller common-battery offices has brought a new type of ringing machine of such a capacity that it will take its place between the two types already in use. In one type of these present machines, used principally in the smallest offices and in private branch exchanges, battery current is converted into alternating current for ringing by a vibrating-reed interrupter and a transformer. Although this apparatus is satisfactory at the switchboards for which it is intended, by its nature it does not regulate voltage closely enough for offices presenting a greater variety of ringing conditions. It is intended for switchboards at which ringing is controlled manually and at which busy signals and other information are given by voice, rather than by signal tone. No provision is made, therefore, for intermittent current for machine ringing, or for signal tones.

Where requirements call for interrupted currents and tones for signalling, and for ringing current controlled by the machine rather than by the operators, a ringing machine of the other type — Type P — has been used. In this, a motor driven alternator furnishes twenty-cycle voltage and rotating drums interrupt the ringing and signalling currents as required. The capacities of these machines, ranging from one to eight amperes, make them adequate for the largest offices, and their output voltage and frequency, which are controlled by regulators, are sufficiently close for the most severe conditions. For the smaller offices using machine ringing, however, certain of the properties of these ringing generators have not been needed. Regulation is considerably closer than is necessary in many such offices, and the current output of the smallest Type P machine exceeds requirements of maximum traffic by a substantial margin.

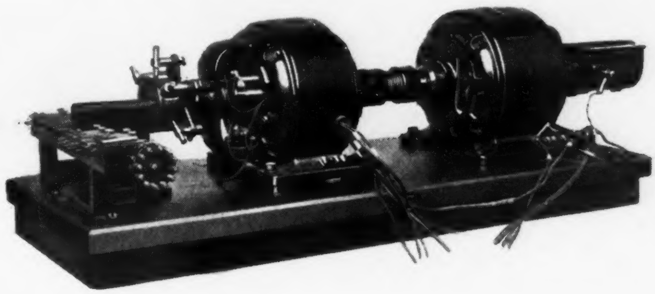
The new machines have therefore been designed to embody only those features useful in offices with a busy-hour traffic of three thousand calls or less. A small twenty-cycle motor-generator set was selected, and high-speed interrupters were added for busy and other tones, a commutator for pulsating current, and low-speed interrupters to make possible the connections needed for machine ringing. The generator has a capacity of a half ampere, delivered at 72 to 88 volts. No voltage regulator on the output has been provided. In the case of the battery-driven sets for which the input voltage may vary between twenty and twenty-eight, a centrifugal regulator has been provided to hold the speed between 1100 and 1200 revolutions per minute. The generator voltage is held within sufficiently close limits by additional field windings in series with the mo-

tor armature. Neither the regulator nor the compound winding will be required for machines to be driven by central-station power.

On the generator shaft are two slip-rings and a ring for delivering pulsating current. Tones of 480 and 160 interruptions per second are secured by a brass drum on an extension of the generator shaft; one brush feeds direct current to the drum, and two pairs of collecting brushes pick up the interrupted currents. The low-speed interrupter, at the end of the machine, is driven by a worm-gear. Instead of another drum with intermittent insulated areas in the path of the brushes, there is a group of rotating discs which bear rollers near their circumferences. During rotation each set of rollers operates a group of flat contact springs, similar to the spring pileup of a key or a relay, which make and break contact 60 or 120 times per minute for signalling current, or connect and disconnect ringing current at the standard ringing intervals. No provision has been made for current to collect and return coins, but that can be supplied readily in these small offices, by a bank of dry cells or otherwise.

An autotransformer, not shown in the picture, is provided for P. B. X. and toll ringing current, and for districts where the subscribers' ringers require slightly different voltages. It is also used when the voltage is near the lower limit to step it up for testing the tripping relays. When the voltage rises, a relay switches the testing circuit to the generator terminals.

The whole set, except for the transformer, is mounted on a slate slab which in turn is screwed onto a wooden base. One machine is adequate in capacity, but two will ordinarily be provided to insure continuous service. The light weight and compactness of the sets make it possible to mount them on a pipe framework, one above the other; the floor space needed is thus reduced to less than half of that occupied by two type P ringing machines.



The new ringing machine, mounted on its slate and wood base. The motor-speed regulator is at the extreme right

Economy is not restricted to floor space, however; two of the sets cost less than half as much as two of the type P sets which would otherwise be needed for an office. The resulting reduction in the power-plant cost will have a tendency to extend the application of machine ringing in the smaller offices.

West Side Motor Highway

Members of the Laboratories are naturally attentive to civic enterprises affecting the convenience of transportation to and from 463 West Street and the appearance of its environs. West-side improvement projects have been under discussion for some time and have taken many forms. The Board of Estimate of the City of New York has recently approved plans for an elevated express motor highway along the west side of the city.

The highway will extend from Canal Street to Seventy-second Street. Consisting of two roadways, each thirty feet in width, it will provide for three lines of traffic in each direction. Sets of ramps about a mile apart will furnish access to the highway at points other than its termini. Four ramps with ten-foot roadways will compose each set, affording ascent and descent to uptown and downtown traffic. From Canal Street to Fifty-ninth Street the highway will be supported on sets of three columns. The sets will be about sixty feet apart, except where the highway spans cross-streets, and the columns of each will be thirty-four feet apart.

Proceeding along West Street, the highway will pass about seventy feet west of the front of our building. The nearest set of ramps will be somewhat south of Twenty-third Street; the picture above shows the anticipated highway at that point. Ending conveniently near the Holland Tunnel, and connecting with the Hudson River Bridge, the highway will yet further facilitate automobile passage between the Laboratories and New Jersey.

The section from Canal Street to Fifty-ninth Street will cost about $16,000,000 and will be financed by assessment on the taxpayers of the Borough of Manhattan. It is expected that work on this section will begin in a month or two and will continue for about three years.

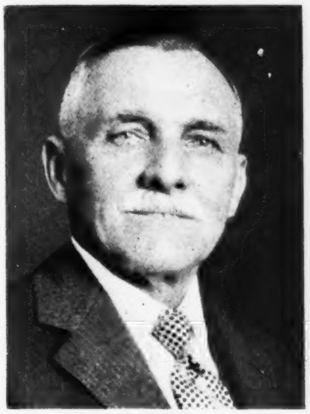
Service Honors for 1928

MORE THAN THIRTY YEARS

Arthur E. Peterson
Research Department
Thirty-five years

Wilton L. Richards
Consulting Historian
Fifty years

Arnold S. Bertels
Systems Development
Forty years



Conrad Schaul
Development Shop
Thirty-five years

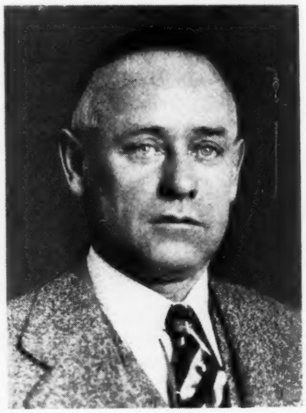
John F. Toomey
Systems Development
Thirty-five years

Adolph Bregartner
Systems Development

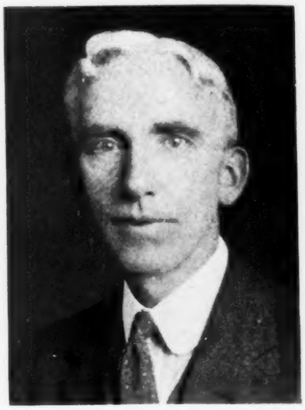
THIRTY YEARS

Frederick E. Anderson
Systems Development

Goodwin Rosenblum
Development Shop



Albert J. Ketschke
Research Department



William McA. Smith
Systems Development

Edward J. Harrington
Development Shop

George Thompson
Systems Development

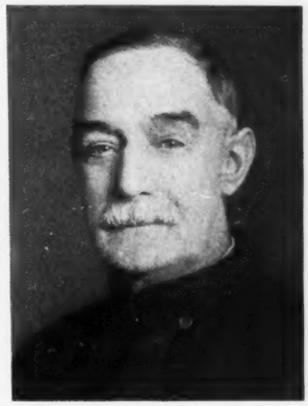
John J. Lohrey
Development Shop

TWENTY-FIVE YEARS

Lee R. Laird
General Staff

Adolph Sulzmann
Research Department

Charles Borgmann
Manual Equipment Engineer



George Hatcher
Plant Operation

George Hess
Plant Construction

Sergius P. Grace
Assistant Vice-President

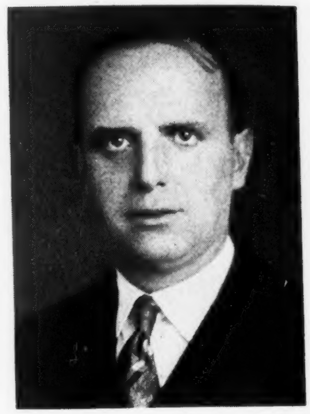
TWENTY-FIVE YEARS

Roy R. Ireland
Specifications Engineer
Apparatus Development

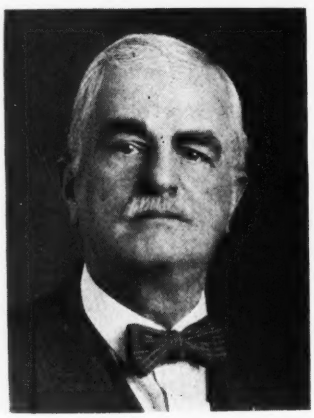
Joseph Irish
Systems Development

Anthony Verrastro
Plant Construction

Arthur K. Forsyth
Apparatus Development



George Dodd
Apparatus Development



George F. Morrison
Power Engineer
Plant Operation

Charles H. Klein
Apparatus Development

News Notes

DR. JEWETT attended an assembly luncheon of the Boston Chamber of Commerce at Boston on January 10 and spoke on "The Romance of Research in the Telephone Industry."

ON DECEMBER 29, Dr. Jewett contributed to a symposium on the "Organization of Scientific Research in Industry", at a meeting of the American Association for the Advancement of Science. His subject was "Finding and Encouragement of Competent Men."

J. E. MORAVEC has been appointed Assistant Vice-President in charge of Staff Department, effective January 14. His organization is as follows: J. W. Farrell, Secretary and General Attorney, in charge of the Legal Department; W. B. Wallace, Treasurer, in charge of the Financial Department; E. J. Santry, General Auditor, in charge of General Accounting Department; B. B. Webb, Commercial Relations Manager, in charge of Commercial Relations Department; J. S. Hartnett, General Service Manager, in charge of the General Service Department; W. B. Sanford, Plant and Shops Manager, in charge of Plant and Shops Department.

R. B. BONNEY, Educational Director of the Mountain States Telephone and Telegraph Company, was a guest of the Laboratories January 2 to 16 for an extended inspection of the facilities here and for observation of current developments. On account of his interest in college relations work, he wanted, among other objectives, a general picture of the Laboratories as a research organization, and information on studies now in progress.

AT THE JANUARY 7 MEETING of the Colloquium, J. A. Becker spoke on "The Science of Coated Filaments". On January 21, J. E. Harris spoke on "Application of the Phase Rule to Metallurgical Problems".

R. B. BONNEY

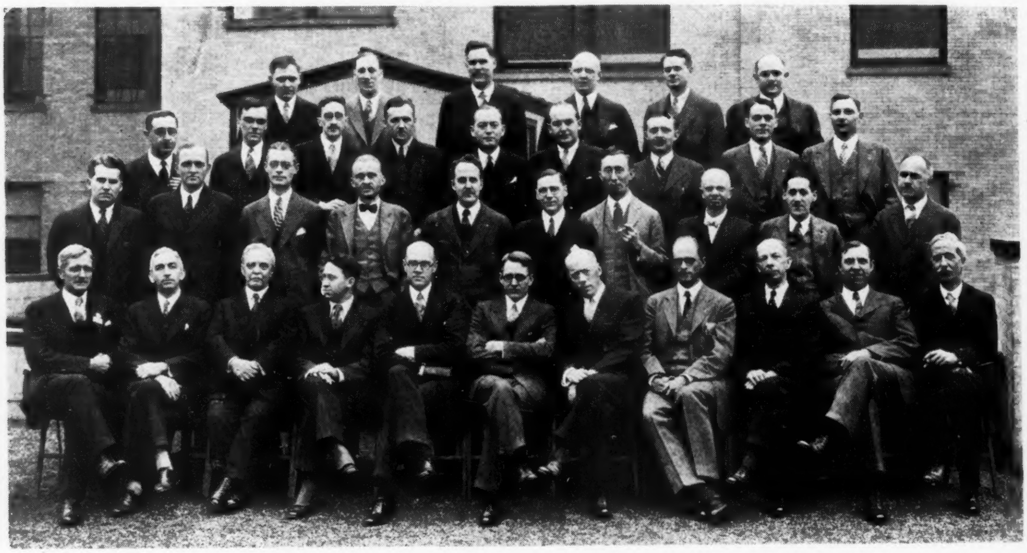
THE ACOUSTICAL SOCIETY OF AMERICA was formed at a meeting held here on December 27, for the purpose of bringing together workers in all branches of pure and applied acoustics. Among its activities will be the provision of a medium of publication for papers on acoustics, for

which there is acute need; such papers have hitherto been widely scattered.

Elected to temporary office were: President—Harvey Fletcher of the Laboratories; Vice-President—Professor V. O. Knudsen of the University of California; Secretary—Wallace Waterfall of the Celotex Company; Treasurer—C. F. Stoddard of the American Piano Company. A committee was appointed by Dr. Fletcher to consider the details of organization, and the first regular meeting will take place here some time in April. There were present forty of the leading authorities on acoustics, among whom were Professor D. C. Miller of the Case School of Applied Science, Professor F. A. Saunders of Harvard University, J. P. Maxfield of the Victor Talking Machine Company, R. V. Parsons of the Johns Manville Company, and Professor F. R. Watson of the University of Illinois. After the meeting, Dr. Arnold entertained the members at luncheon.

Inspection Engineering

J. A. St. Clair, San Francisco



Members of the Acoustical Society of America: left to right: back row: W. P. Mason, B.T.L.; J. C. Steinberg, B.T.L.; V. L. Chrisler, Bureau of Standards; E. J. Schroeter, Macoustic Eng. Co.; E. C. Wente, B.T.L.; W. C. Jones, B.T.L.; second row from back: L. J. Sivian, B.T.L.; E. L. Norton, B.T.L.; W. A. MacNair, Victor Co.; R. F. Mallina, Victor Co.; Lonsdale Green, Jr., Johns-Manville Corp.; R. H. Schroeter, Macoustic Eng. Co.; H. W. Lamson, Gen. Radio Co.; C. N. Hickman, American Piano Co.; D. G. Blattner, B.T.L.; second row from front: H. A. Erf, Northern Ohio Tel. Co.; H. C. Harrison, B.T.L.; J. B. Kelly, B.T.L.; R. L. Wegel, B.T.L.; H. A. Frederick, B.T.L.; N. R. French, A. T. & T.; C. W. Hewlett, G. E. Co.; A. T. Jones, Smith College; Irving Wolff, R.C.A.; J. B. Taylor, G. E. Co.; front row: F. A. Saunders, Harvard U.; R. V. Parsons, Johns-Manville Corp.; D. C. Miller, Case School of Applied Science; Wallace Waterfall, Celotex Co.; V. O. Knudsen, U. of California; H. Fletcher, B.T.L.; C. F. Stoddard, American Piano Co.; J. P. Maxfield, Victor Co.; F. R. Watson, U. of Illinois; F. K. Richtmeyer, Cornell U.; G. R. Anderson, U. of Toronto

Field Engineer, visited Seattle, Tacoma, Portland and other cities in Washington and Oregon during the second week in December in connection with Field Engineering duties.

A. F. Gilson and P. S. Olmstead attended a regular survey conference on telephone receivers at Hawthorne during the latter part of December.

W. A. Boyd, in company with a committee for the study of protective metal finishes, visited Norfolk, Atlanta, Birmingham and New Orleans during the early part of January.

A. G. Dalton and R. J. Nossaman visited Philadelphia during the latter part of December in connection with Field Engineering work.

H. F. Dodge was the author of an article "Using Inspection Data to Control Quality", which appeared in Manufacturing Industries for November and December.

Research

E. F. Kingsbury addressed the Women's Club of Rutherford, New Jersey, on television on January 7.

Among papers presented before the American Physical Society at its midwinter meeting at Columbia University were "The Maximum Excursion of the Photoelectric Long Wave Limit of the Alkali Metals", by H. E. Ives, read on December 27, and "A Wave Mechanism of Quantum Phenomena" by R. V. L. Hartley, on December 29. On the latter date, a paper "Anomalous Dispersion of Electron Waves by Nickel", by C. J. Davisson and L. H. Germer, was also given.

T. C. Fry was one of the presiding officers of a joint meeting of the Mathematical and Physical Societies.

H. A. Frederick attended a meeting of a committee of the National Research Council on "Substitutes for Sound" at St. Louis on December 8.

George Knapp gave an illustrated talk on television at the Columbian Club at Elizabeth, New Jersey.

A. W. Hayes worked on handsets at Hawthorne recently.

G. R. Yenzer was at Hawthorne on December 10 in connection with resistance requirements for condenser transmitters.

R. M. Burns inspected some instances of corrosion in central offices at Atlantic City on December 3 and 4.

B. L. Clarke made a survey of lubrication problems at Hawthorne and visited centers of lubrication research at Washington, Minneapolis, Madison and Pittsburgh.

C. L. Hippensteel and C. W. Borgmann discussed corrosion problems with engineers of the New Jersey Zinc Company at Palmerton, Pennsylvania.

A. R. Kemp visited the Columbian Rope Company at Auburn, New York, in regard to cable developments.

R. L. Peek attended the Plasticity Symposium held at Lafayette College in Easton, Pennsylvania.

R. M. Burns and D. J. Salley attended the Soil Corrosion Conference at the Bureau of Standards at Washington and made experimental investigation of protective coatings at Hawthorne, from December 9 to 29.

Harvey Fletcher attended committee meetings on research for the deaf at Washington, D. C., in connection with the Anthropology and Psychology Division of the National Research Council.

R. O. Mercner visited the Vibration Specialty Company at Philadelphia on December 15 to observe the balancing of high-speed machines.

E. C. WENTE's article, "Speech Interpretation in Auditoriums", which appeared in the RECORD for October, has been reprinted in the December issue of the Gamma Alpha Record.

H. ECKHARDT made phonograph records at Houlton, Maine, of transatlantic conversations between Austin Bailey of the Long Lines Department at 24 Walker Street, and Colonel Shreeve, at London, on January 7 and 8. Simultaneously, E. Peterson recorded these conversations at the Laboratories.

OUTSIDE PLANT DEVELOPMENT

C. S. GORDON visited the New York Insulated Wire Company at Wallingford, Connecticut, on December 6 in connection with the preparation of trial lots of drop wire.

E. M. HONAN was in Boston to discuss with members of the Simplex Wire and Cable Company problems dealing with the manufacture of rubber-insulated wire.

C. D. HOCKER AND F. F. FARNSWORTH visited several of the associated telephone companies in the middle west, as well as the plants of several automobile body manufacturers and paint companies, to investigate paint finishes for automotive equipment.

C. Q. LUMSDEN was engaged in studies of chestnut poles at Shipman, Natural Bridge and Waynesboro, Virginia, from December 20 to 22.

GENERAL STAFF

M. B. LONG addressed the Philadelphia Section of the A. I. E. E. on January 14, on the subject of the photoelectric cell and its use in communication. Prior to the meeting, Mr. Long was the guest of the Engineers Club at dinner.

JOHN MILLS spoke on "Electrical Eyes and Their Use in Communication" before the Engineers Club of St. Louis on January 9, the Southwestern Bell Telephone Company employees on January 10, and on January 11, he addressed the engineering students of Washington University. The following day, Mr. Mills spoke on the same subject before the Round Table of the University.

S. P. GRACE addressed the staff of the Carson Peck Memorial Hospital in Brooklyn on January 10, on recent developments of the Laboratories. Mr. Grace also lectured before the Engineers Club of Cincinnati.

T. W. CLARKE has been elected to membership in the Edward J. Hall Chapter of the Telephone Pioneers.

HELEN O. LUEDTKE, a stenographer in the Transcription Department, died on Friday, January 4. Miss Luedtke had been a member of the Laboratories since February, 1926.

H. M. ANDERSON, a shop mechanic in the Plant and Shops Department, died on December 14. Mr. Anderson had been associated with the Laboratories since March 6, 1918.

PATENT

MEMBERS OF THE PATENT DEPARTMENT who went to Washington during the period from December 11 to January 10, in connection with the prosecution of patents were: E. W. Adams, W. C. Kiesel, I. MacDonald, T. P. Neville, J. W. Schmeid and G. H. Stevenson.

APPARATUS DEVELOPMENT

F. F. LUCAS spoke on metallography before the American Society for Steel Treating at Buffalo.

S. J. ZAMMATARO's article, "Development of the Impedance Bridge," which appeared in the RECORD for December, has been reprinted in full

in the January issue of the Sibley Journal of Engineering.

J. R. TOWNSEND's article, "New Specifications for Raw Materials," which appeared in the RECORD for February, 1928, has been reprinted in the December issue of "Instruments."

E. T. MOTTRAM tested film recording machines at Hawthorne.

O. L. WALTER discussed suggested changes in the 202-B reproducer set at Hawthorne.

J. C. HERBER's article, "Frequency Control for Broadcasting", which appeared in the RECORD for September, has been reprinted in the November issue of the Bent of Tau Beta Pi.

S. J. ZAMMATARO AND T. SLONCZEWSKI visited the Leeds and Northrup Company at Philadelphia to inspect shielded-type precision bridges.

H. BROADWELL attended conferences at Hawthorne on the manufacture of precision interrupters.

F. H. HIBBARD visited Chattanooga, Tennessee, and Atlanta, Georgia, in connection with the revision of adjustment requirements on step-by-step relays.

SYSTEMS DEVELOPMENT

W. L. HEARD, as a member of the Standards Committee of the A. I. E. E., has participated in the preparation of graphical symbols for telephone and telegraph use. This work has now been completed, the symbols and abbreviations have been approved as an Institute standard and they are being transmitted to the American Standards Association.

E. H. SMITH spent a week at Chicago discussing step-by-step central-office equipment.

J. R. STONE AND H. L. MUELLER discussed exhaust equipment for pneumatic tube systems and various power machine problems with representatives of the General Electric factory in West Lynn, Massachusetts.

W. O. FULLERTON inspected at Rochester the new 506-A cordless P. B. X. being built by Stromberg-Carlson.

V. T. CALLAHAN discussed gas engine mufflers with members of the Maxim Silencer Company at Hartford, Connecticut.

E. J. KANE AND J. M. DUGUID investigated busy-tone wiring in the step-by-step office at Hartford.

G. E. BAILEY AND R. E. NOBLE recently inspected a new type of superstructure for frames and racks installed at Laurel Springs, New Jersey.

L. P. BARTHELD discussed cabling problems in the new Chicago Toll Office with Illinois Bell engineers.

C. ECKBERG is arranging for installation of improved radio broadcasting circuits at various repeater stations on the Pittsburgh-New York cable.

C. BORGMANN visited Boston, Chicago and Rochester in connection with equipment problems.

W. J. LACERTE visited Hartford and Atlantic City in connection with improved circuit arrangements for step-by-step central offices.

* * *

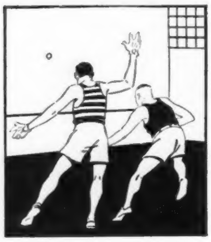
Two corrections should be noted in the RECORD for January.

On page 186, last paragraph, the number of regulators in the Long Lines plant should have been given as 41.

In the second paragraph on page 189 the second sentence should read "Under these conditions on a full size cable there is an IR drop along the cable of about *one* volt per hundred feet . . . "

Club Notes

During the month of March the Club will hold an indoor handball tournament at Labor Temple, Fourteenth Street and Second Avenue, Manhattan. Play will commence Tuesday evening, March 5, and matches will be held on Tuesday and



Thursday evenings from 5:30 to 7:30, for four weeks. The single-wall form of play will be used, and all games will be singles. The tournament will be conducted on an elimination basis, with all matches up to the semi-finals consisting of a single game. Semi-finals and finals will be decided by two games out of three. The winner will receive an order good for ten dollars' worth of merchandise at Alex. Taylor and Company, the second man, an order worth five dollars, and the two men eliminated in the semi-finals will each get an order worth two dollars and a half.

Entry blanks may be obtained from D. D. Haggerty, Room 164, and must be returned to him with the entry fee of twenty-five cents not later than Monday, February 25. Before each round, players will be advised of date, time and opponents with whom they have been matched.

Indoor Golf

Plans have been completed for the final tournament of the indoor golf season, which will be played on Wednesday evening, February 27, at the Miniature Golf Course of America, 41 East 42nd Street, Manhattan.

As in previous tournaments all contestants will play thirty-six holes of medal play in the qualifying round after which they will be divided into two groups of four flights each with prizes for the winner in each of the eight flights. Sixty-four players will be qualified for the finals.

Entries should be forwarded to D. D. Haggerty, and accompanied by an entrance fee of $1.50.

In addition to the prizes supplied

by the Club, a valuable prize will be donated by the management of the golf course.

Photographic Contest

The annual Photographic Contest, open to all the members of the Laboratories, is now under way. Entries

should reach D. D. Haggerty before March 1, after which date they will be exhibited and judged. Prints are to be divided into four classes: portraits, landscapes, still life and colored transparency. For further information regarding rules and prizes, call Margaret Horne, Extension 786, or D. D. Haggerty, Extension 542.

Glee Club

It is the wish of the music committee that every department of the Laboratories be represented in the Glee Club. The active membership may be divided as follows: Systems Development, 12; Patent, 11; Apparatus Development, 6; Research, 5; Accounting, 2; Inspection, 1.

Trained voices are not necessary, but a fairly good voice and some ability to read music are desirable. The Glee Club is now rehearsing for a formal recital to be held in April as a part of the Spring Dance and Entertainment of the Club. For that reason, new members will not be accepted after March 1. Meetings are held every Wednesday evening from 5:10 P. M. to 6:10 P. M. in the Women's Rest Room on the eleventh floor. For further information call either Ada Van Riper or P. H. Betts.

Bridge

The men's bridge club recently completed its ten-week tournament and on Monday, January 7, and Monday, January 14, sixty men took part in an elimination tournament to determine who would represent the Club in the annual tournament with the Western Electric Bridge Club. This match will be held on Monday evening, March 4, at 195 Broadway, and forty players from each company will compete for the trophy, now held by the players from Western Electric.

A second tournament of ten weeks' duration was started by the members of the Club on Monday evening,

January 28. This group meets each Monday evening in Rooms 275 and 277 and the committee in charge is always glad to welcome new players.

The women's bridge club played the first game of the mid-winter tournament on Friday, January 5th. The tournament will continue for ten weeks and in order to be eligible for tournament prizes players must take part in at least seven out of the ten games.

The bridge club conducts a meeting every week, at which prizes are given for high scores. Those interested may apply to Mary V. Lynch.

Symphony Orchestra

Until further notice the orchestra, which formerly met on Thursday evenings, will meet on Tuesdays at 5:05 in the Women's Rest Room. A buffet supper will be served by the restaurant management in the Rest Room at 5:45.

The orchestra, for a time under the leadership of Mr. Egon Eibert, a professional conductor, is again being conducted by L. E. Melhuish. Mr. Melhuish stresses the fact that, although regular attendance at rehearsals is desirable, the program for the remainder of the season has been so arranged as to make it interesting for those who cannot attend each of

the weekly meetings of the orchestra.

A class of music suitable to the number attending rehearsals will be undertaken. Members are encouraged to suggest selections for rehearsals, which the club in turn will be glad to procure. The repertoire now consists of standard overtures, operatic selections, symphonies and popular selections from musical comedies.

Women's Bowling

The second half of the bowling season begins with a reorganization of the women's bowling group under the supervision of a committee of men, appointed by the General Chairman of the men's bowling league. This committee is looking after the interests of the women bowlers, with a view to promoting an enthusiastic and successful season.

Arrangements may be made

through Antoinette Kelly or Marian Kane to have one's name placed on the substitute list.

With the close of the bowling season, a dinner and theatre party will be given to the bowlers. At dinner, prizes will be awarded to the winners.